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The "No Child Left Behind Act" signed into law on January 8, 2002 places strong emphasis on state accountability for educational results and use of teaching methods that have been shown to work [see http://nclb.gov/next/overview/]. For science educators, these expectations underscore the need to fully implement the National Science Education Standards (National Research Council (NRC), 1996) by attending to

the multifaceted conditions in schools in a holistic and systemic manner. The challenge for the research community is to identify the most critical aspects of the needed research, conduct the research, and provide the educational community with the research-based information needed to move forward with science education reform. There are significant gaps in our knowledge of the science education reform process, and the existing body of research highlights specific areas where additional understanding is of central importance to successful reform.

WHAT WE KNOW

A review of extant research (Anderson & Helms, 2001) provides the basis for the following generalizations about efforts to promote broad reform congruent with the vision of the "National Science Education Standards" (NRC, 1996):

* The dramatic changes called for in the Standards are very difficult to put into full practice and where attempted generally fall short of the mark.

* The difficulties of making the desired changes are highlighted by the many dilemmas teachers face in the process. Some of the dilemmas teachers experience (Anderson, 1995, 1996) relate to time constraints, tensions between the ideal and classroom realities, changing roles for students and teachers, overcoming traditional views of preparing students for the next level of schooling, and issues related to equity, such as tracking and ability grouping.

* Fundamental reform requires significant changes in teachers' values and beliefs about science education practices. Though the relationship between teachers' beliefs about the nature of science and their views of schools and pedagogy is unclear, teachers' views of students in terms of ability, gender, and ethnic identity do seem related to their pedagogical decision making (Bianchini, Cavazos, & Helms, 1999).

* Departments within schools are the most important setting for change, although most research addresses whole school change.

* Substantial teacher collaboration in the work context--not just in inservice

education--can be a powerful changing influence on teachers' values and beliefs. A significant barrier to substantive change comes from a lack of attention to the ways in which teachers come to hold certain beliefs, values, and assumptions with respect to students' roles, pedagogy, and the science curriculum.

* Parents often resist reforms and they have a strong influence on science education reform efforts; without local parental support of the reform ideas and practices, their implementation fallsshort.

* The recommended reforms demand new student roles and different student work. It is the "bottom line" of science education reform, and it is the area in which almost all reforms fall short, even when teachers have made substantial changes in their own roles and practice.

WHAT WE DO NOT KNOW

Following are topics important both to practitioners and policy makers, but we do not have a good understanding of these matters. Thorough investigations are needed.

* The most productive roles for students when addressing science content in ordinary classroom settings are not known in any practical detail.

The modes of learning called for in the Standards imply markedly different roles for students in terms of designing laboratory investigations, processing information, and engaging in such mental processes as interpreting, explaining, and hypothesizing. Given the knowledge we have, it is clear that these roles cannot be studied very effectively in isolation because their implementation interacts so deeply with changes in teachers' roles and various teacher values and beliefs.

* In addition to student roles, the nature of the desired student work and the means of engaging students in it within ordinary classroom contexts, are not known in any practical detail.

The new student roles imply that students will direct much of their own learning, that learning tasks will vary among students, and that these tasks will emphasize reasoning, reading and writing for meaning, solving problems, building from existing cognitive structures, and explaining complex problems. The range and nature of these tasks in various specific science contexts are not well understood; in fact, there is a dearth of studies on desired student work.

* How teachers can best be engaged (over a period of years) in reassessing their personal values and beliefs and taking major personal responsibility for acquiring needed new professional competencies is not well understood.

The research tells us that teacher collaboration is powerful, but it has not been studied as a specific means of addressing these particular aspects of science education reform. To be fully understood, this situation must be studied from multiple perspectives, in particular from psychological and socio-cultural perspectives.

* It is not clear how to involve parents most effectively in the science education reform process so that they are educated about the issues involved and can influence their children's education most positively.

It is clear that parents can have a strong influence on efforts to change science education practice, and research indicates that teachers provide a key interface between parents and schools. There is, however, an insufficient research base for deciding the best course of action for schools to take to inform parents and productively engage them in the reform process.

* How to address the increasingly acute equity and diversity issues in a climate of science education reform is not well understood.

"Research efforts," Lee (2000) claims, "generally involve identifying educational problems or describing instructional practices rather than implementing intervention strategies to promote teacher effectiveness or student achievement. Research is still at

the stage of conceptualizing issues that need empirical testing." A recent forum on "Diversity and Equity Issues in Mathematics and Science Education-What do We Know? What Do We Need to Know?" (Britton, Raizen, Kaser, & Porter, 2000) offers specific recommendations regarding the research needed in this important area.

CHARACTERISTICS OF NEEDED RESEARCH

The multidimensional challenges listed above call for a variety of holistic and systemic approaches to research. Scholarship must be "holistic" in the sense of giving simultaneous attention to all of the many elements and perspectives that are part of the picture. They must be "systemic" in that attention is given to the many "interactions" among the various elements and the influences they have on each other.

Multiple Perspectives

Broad, comprehensive studies from a multiplicity of perspectives--psychological, sociological, cultural, organizational, political, economic, philosophical, and subject matter--are needed. Then, scholarly syntheses of studies conducted from various perspectives will need to follow. Our poor understanding of "science for all" underscores our need to study science classrooms as communities of practice, and teachers as communities of professionals.

Conduct Research in the "Real World"

Studies are needed in ordinary school contexts, with ordinary levels of resources, and ordinary outside help.

Study Interventions

Researchers need to study a variety of specific interventions having certain intended outcomes. Interventions chosen and initiated by teachers must be central, and they should include those influencing parents, teachers, and students.

Not Based on Assumptions that Change Comes from the Top Down

The inadequacies of interventions that are solely top-down are well established in the research literature (Sarason, 1996).

Interpretive Research

The multiplicity of interacting variables in the matters under study is such that controlled experiments with full prior delineation of all variables are largely impossible. The goal is to make interpretations of this complex situation that will make it possible to assist practitioners in changing practice and aid policy makers in setting better policy. This need places a premium on research that attends to the many relevant variables, their interactions, and various interpretations of the complex situations.

Focus on Students Roles and Student Work

The roles played by students and the nature of the work they do constitute the "bottom line" of educational reform, yet the specifics of desired roles and the most beneficial student work are not clear. These matters must be at the center of research in this area.

Give Major Attention to Teacher Learning

Past research points to teacher learning as being central to reform, and that the most important dimension of learning has to do with values and beliefs. What is not fully understood are the nature of needed changes and the circumstances under which teachers personally can best reassess relevant values and beliefs.

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